OBITUARY NOTICES OF FELLOWS DECEASED.

JAMES THOMSON, lately Professor of Civil Engineering and Mechanics in the University of Glasgow, was born in Belfast on February 16, 1822.

His father, a mathematician of very high order, was, in the first instance, Mathematical Master and Professor of Mathematics in the Royal Belfast Academical Institution; but in 1832 became Professor of Mathematics in Glasgow University.

James Thomson, and his brother William, Lord Kelvin, entered the classes at Glasgow University at an unusually early age. They were never at school, having received their early education at home from their father. They passed through the University together, both with high distinction, the two lads usually obtaining the first and second prizes in each of the classes they attended.

At a very early age also James Thomson showed evidence of considerable inventive genius. When he was about sixteen or seventeen he invented a mechanism for feathering the floats of the paddles of paddle steamers. Steamboats, even on the Clyde, were comparatively novel in those days; and the invention was looked on with much interest by the Clyde engineers to whom it was shown. Unfortunately, from a commercial point of view, however, it turned out that another method of accomplishing the same object had been invented and patented only a few months earlier.

After passing through the University curriculum, James Thomson took the degree of M.A. with honours in Mathematics and Natural Philosophy at the age of seventeen.

As he had decided on adopting civil engineering as his profession, he went, in the autumn of 1840, to the office of Mr. Macneill (afterwards Sir John Macneill), in Dublin. But unfortunately his health had, shortly before, to some extent, broken down. He was obliged to leave Mr. Macneill's office after about three weeks and return home.

In 1840 a new departure was made in Glasgow University, which proved of great importance, and which has had far-reaching influence on the practical teaching of engineering in this country. This was the foundation, by Queen Victoria, of the first Chair of Civil Engineering and Mechanics in the United Kingdom. The first professor was Lewis Gordon, who was succeeded fifteen years later by Macquorn Rankine. James Thomson, at home and in delicate

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health, attended Professor Gordon's classes in engineering, and was busy with inventions of various sorts; and particularly with a curious boat, which, by means of paddles and legs reaching to the bottom, was able to propel itself up a river, walking against the stream.

In 1843 he was able to resume work as an engineer, and he went to Millwall, to the works of Messrs. Fairbairn and Co., of London and Manchester. He was not, however, able to remain with them for the full time of his apprenticeship. Illness returned; he was obliged to go home; and this illness proved the commencement of a period of delicate health which lasted for years, and, indeed, produced a permanent effect on his whole life.

During the months which he spent at Millwall, he was busy with improvements in furnace construction for the purpose of prevention of smoke. The gases of combustion were to be taken downwards through the furnace instead of upwards; and the fire bars were to be tubes with water circulating through them.

After his return to Glasgow he was obliged to confine himself to work which did not involve bodily fatigue. He occupied himself much with invention; and particularly gave his attention to machines for the utilisation of water power.

He constructed a horizontal water-wheel, which he named a Danaide, being an improvement on the Danaide of Manouri Dectot; and somewhat later, after much investigation and research, he invented a wheel which, from the nature of its action, he called the vortex water-wheel. This form of wheel was patented in 1850. It was an important advance on water-wheels of previous construction. The moving wheel was mounted within a chamber of nearly circular form. The water, injected under pressure, was directed, by guide blades, to flow tangentially to the circumference of the wheel; and was led through the wheel to the centre by suitably formed radiating partitions. Thus the water yielded its kinetic energy derived from one half of the fall, and its potential energy from the other half, to the wheel by pressure on the radial partitions, as it passed inwards to the centre, whence it quietly flowed away in the tail-race. A considerable number of these wheels were designed by him for various factories and for different purposes. They were made and supplied by Messrs. Williamson Bros., of Kendal, and gave much satisfaction.

In 1847 his mind was also busy with a question to which at a later date he gave much thought and labour, and to the solution of which he made contributions of great importance. On April 5 of this year there appears a memorandum in his handwriting:—"This morning I found the explanation of the slow motion of semi-fluid masses such as glaciers."

During 1848 his first three important scientific papers were published. The first of these was on "Strength of Materials as

influenced by the existence or non-existence of certain mutual Strains among the Particles composing them." The second was a remarkable paper on "The Elasticity and Strength of Spiral Springs and of Bars subjected to Torsion." In this paper the action of a spiral spring was explained, and important principles connected with the subject of torsion were brought forward. These papers were published in the 'Cambridge and Dublin Mathematical Journal,' November, 1848.

The third was, perhaps, yet more remarkable. It was contributed to the Royal Society of Edinburgh, and was on "The Parallel Roads or Terraces of Lochaber (Glenroy)." These remarkable *terraces* or *shelves* had attracted much attention. Darwin, Lyell, David Milne, Sir G. Mackenzie, Agassiz, Sir Thomas Dick Lauder, and others had discussed the causes of their formation. James Thomson, however, gave in this paper what is now the accepted explanation.

Curiously, Professor Tyndall seems not even to have known of the existence of the paper when he gave his admirable exposition of this wonderful natural formation at the Royal Institution in 1876. He attributes the explanation of the Parallel Roads to Jamieson, 1863; whereas the whole theory had been given by Thomson in 1848 in the paper just mentioned with details as to necessary climatic circumstances, not noticed by Tyndall.

In January, 1849, he communicated to the Royal Society of Edinburgh a paper of great importance, which was printed in the 'Transactions' of the Society, and was afterwards republished, with some slight alterations by the author, in the 'Cambridge and Dublin Mathematical Journal,' November, 1850. The title of this paper was "Theoretical Considerations on the Effect of Pressure in lowering the Freezing Point of Water." The principles expounded in this paper were afterwards, in 1857, used as the foundation of his well-known explanation of the plasticity of ice, discovered by Forbes; and later, from 1857 onwards, for several years, the whole subject afforded him much food for thought; and extensions and developments in various directions followed. The paper of 1849 was of great intrinsic importance. In it, by the application of Carnot's principle, an absolutely unsuspected physical phenomenon was discovered and predicted, and the amount of lowering of the freezing point of water was calculated. The phenomenon was shortly after experimentally tested and confirmed by his brother, Lord Kelvin.

But the paper has another title to interest, which is not so generally known. In it for the first time Carnot's principle was stated, and Carnot's cycle described, in words carefully chosen, so as not to involve the assumption of the material theory of heat, or rather, as Thomson himself puts it, the supposition of the "perfect conservation of heat."

For the sake of clearness, it may be well to leave here for a moment the chronological order of James Thomson's life, and to explain briefly the subsequent development of the ideas first disclosed in this paper of 1849.

Forbes had discovered, by observations and experiments on the Swiss glaciers, the property of *plasticity* in ice. The fact of plasticity in ice was at first doubted; but it was afterwards admitted, and various explanations were offered of this property, so remarkable in a brittle and, above all crystalline, substance.

In this connection, Faraday called attention to the freezing together of two pieces of ice placed together in water; and from this arose a partial explanation, by Tyndall, under the designation of "Fracture and Regelation." But the theory, and even the not logical juxtaposition of the two words, did not satisfy James Thomson. There was nothing to show why or how reunion (or "regelation") should take place after fracture. He saw, however, that an extension of his own previous principle of lowering of the freezing point by pressure allowed him to apply it to the effect of distorting stress on solid ice, and would give a perfect explanation of all Faraday's observations and experiments on the union and growth of the connecting link between two pieces of ice under water, pressed together by any force, however small.

By this extended thermodynamic principle he also accounted for the yielding of a mass of ice crystals (dry snow, for instance) at *temperatures lower than the ordinary freezing point*. He demonstrated that the mutual pressures must melt the ice at, and close around, the points of contact; and that, when there is relief from the internal stress by this melting, the low temperature of the main solid mass, and the extra cold due to the latent heat required for liquefaction of the yielding portions, cause the melted matter to re-freeze in the places to which it has escaped in order to relieve itself from strain. Thus a complete explanation, based on a demonstrated physical principle, was offered of the phenomenon.

Thomson's explanation did not, certainly at first, commend itself thoroughly to Faraday. A very interesting correspondence between them ensued; and Faraday made a number of beautiful and interesting experiments, with the object of showing that the placing of two pieces of ice on opposite sides of a film of water (between them) would give rise to the conversion of the film of water into ice, and cause the union of the two pieces of ice, the principle being that of the starting of crystallisation in a supersaturated solution by means of a crystal of the solid. James Thomson, however, showed that, in the experiments adduced by Faraday, pressure between the ice blocks was not absent. For example, in an experiment in which two pieces of ice, with a hole through each, were mounted on a horizontal rod of

glass, he pointed out that the capillary film of water between the slabs draws them together with not inconsiderable mutual pressure, and hence the freezing. Thomson further showed that when two pieces of ice are brought to touch each other at a point wholly immersed under water, and thus free from capillary action, the most minute pressure pushing the two together causes the growth of a narrow connecting neck, which may be made to grow by continued application of the pressure; while the application of the smallest force tending to draw the two asunder causes the neck to diminish in thickness, and finally to disappear.

In later years James Thomson further developed the theory of 1849. He showed that stresses, of other kinds than pressure equal in all directions, can relieve themselves by means of local lowering of the freezing point in ice; and he showed, by theory and by experiment, that the application of stresses may assist or hinder the growth of crystals in saturated solutions. Some of these conclusions are of such importance that they deserve to be better known. The title of the paper in which the last-named results were given is, "On Crystallisation and Liquefaction as Influenced by Stresses tending to Change of Form in the Crystals,"* 1861. It included the amended and extended theory of the plasticity of ice.

In 1850, James Thomson was engaged in perfecting his design for the Vortex water-wheel. He had soon some orders for the wheel; and in 1851 he took the important step of settling down as a civil engineer in Belfast.

His business grew by degrees. His health improved, and we find him occupied in the next two or three years with scientific investigations as to the "properties of whirling fluids." This led to improvements in the action of blowing fans on the one hand, and, on the other, to the invention of a centrifugal pump and to improvements in turbines which were described to the British Association at Belfast in 1852. At this meeting, also, he described "A Jet Pump, or Apparatus for drawing up Water by the Power of a Jet"; and these investigations led to the designing, on the large scale, of pumps of this kind. Some of these pumps have done important work in the drainage of low lands at places where a small stream, capable of supplying the jet, can be found in the immediate proximity. His investigations on the mechanics of whirling fluids, again, led to the design of great centrifugal pumps, the largest of which are now at work on sugar plantations in Demarara.

It will thus be seen that he was giving much attention to water engineering; and in November, 1853, he became resident engineer to the Belfast Water Commissioners, a post which he occupied till the end of 1857.

* 'Roy. Soc. Proc.,' Dec. 5, 1861.

In this year he was appointed Professor of Civil Engineering and Surveying in Queen's College, Belfast. He became fully occupied with the duties of his professorship, and gave up his office and business as a civil engineer, except for the connection which he retained with some of his former clients, and for business in consultation.

The professorship in Belfast he held till the death of Macquorn Rankine in 1872. By this event the Professorship of Civil Engineering in Glasgow became vacant; and James Thomson was in the next year appointed by the Government to succeed him.

In 1888 his sight unfortunately began to fail; and the malady, from which both his eyes suffered, proceeded so far that it became necessary for him to resign his University work. This he did after the end of the session 1888–89. Happily, however, he retained more or less of his eyesight till the end of his life; and as he became more accustomed to the condition of his eyes he was better able to make use of what remained to him, and was able to move about freely with but little assistance, and even to read and write a little, and to make on a large scale the diagrams which he used to illustrate his Bakerian Lecture on "The Grand Currents of Atmospheric Circulation."

His death was almost sudden and was the beginning of a sadly tragic time in his family. In a single week Professor Thomson, his wife, and youngest daughter were all attacked with cold, which was quickly followed by inflammation of the lungs. The next week saw the death of all three; his daughter surviving him only three days, and Mrs. Thomson seven days. Professor Thomson's death took place on the 8th of May, 1892.

It is not possible in the limits to which this notice must be confined to refer to all James Thomson's papers, nor to give a complete list of the many subjects which occupied his attention.

Already some of his contributions to thermodynamics have been mentioned; but it must be further remarked that during the portion of his life which was occupied with teaching, he gave great attention to this subject, endeavouring to improve the nomenclature and modes of expression of the various principles and propositions connected with it, and to simplify modes of explanation and of statement.

Another very remarkable contribution to thermal science and thermodynamics was his extension of Andrews' discoveries on the subject of the continuity of the liquid and gaseous states of matter. Thomson's mode of conception of the whole subject, which led to the construction of a model in three dimensions to show the mutual relations between pressure, volume, and temperature of such a substance as carbon dioxide under continuous changes of pressure, and volume, and temperature, was perfectly new and most important. The model itself threw a flood of light on the question and the imagining of the

extension of the three-dimensional surface so as to include an unstable condition of the substance, partially realisable and even well known in the phenomena of a liquid passing its boiling point without forming vapour, and in similar unstable conditions, was an advance in the theory of this important question, the consequences of which are not even now completely realised. The verification of Thomson's theories on this subject has proved a fruitful field of experimental investigation for many workers.

Another subject of great importance to which Professor James Thomson devoted much thought and attention was that of safety and danger in engineering structures, and the principles on which their sufficiency in strength should be estimated and proved. He made more than one weighty communication on this subject to engineering societies; and on his appointment at Glasgow, in 1873, he made it the subject of the Latin address which it is the custom for a newly elected Professor to read to the Senatus of the University of Glasgow. An address in English on the same subject became his inaugural lecture to the students of his class in engineering.

When he took up the question, about 1862, he felt that ordinary engineering practice as to testing of structures, boilers for example, was both illogical and unsafe. He considered that the tests usually applied were quite insufficient to permit of an engineer feeling justified in risking the lives of men and the property of his employers to the dangers of breakdown. It was then a common opinion that severe testing should not be applied lest the structure should be weakened by the test itself; but Thomson denied that the test does weaken the structure if the structure be good; and pointed out that the real reason for not applying a proper test was, frequently, fear lest the structure should be found far inferior in strength to that which it was intended to have. The truth of Professor Thomson's contentions is now admitted by the highest engineers; and the best engineering practice has, happily, undergone a thorough reform in this respect.

Certain geological questions possessed much interest for James Thomson. We have seen how, at an early age, he investigated the parallel roads of Glen Roy; and on many subsequent occasions he examined with great care the places where he chanced to be residing, and found and described glacier markings. He traced out, on more than one occasion, specially interesting features of the ice action, endeavouring to determine, by means of an examination of the markings, details as to the motion of the ice, whether in the form of glacier or in the form of icebergs taking the ground in shallow waters.

His attention was also directed to the jointed prismatic structure seen at the Giant's Causeway in Ireland, and elsewhere. No satis-

factory explanation of this remarkable phenomenon had been given. The old theories, involving a supposed spheroidal concretionary tendency in the material during consolidation, seemed quite untenable. He examined with great care the appearances presented in the surfaces of the stones, and concluded that the *columnar* structure is due to the shrinking and cracking during cooling of a very homogeneous mass of material. The *cross joints* he considered to be in reality circular conchoidal fractures commencing at the centre of the column and flashing out to the circumference.

A very interesting subject, and one of very high importance, to which Professor Thomson gave great attention, is the flow of water in rivers. He investigated, with great care, and from a theoretical point of view, the origin of windings of rivers in alluvial plains, and his conclusions were published in the 'Proceedings of the Royal Society,' May 4, 1876. Later in the same year he constructed, in clay, on a table, a model with which he investigated the movements of the different parts of the water in passing round the bends in this artificial river; and, finally, he made a large wooden model of a river flowing on a nearly horizontal bed with many bends and various obstacles. By aid of fine threads, small floating and sinking bodies, and coloured streams of fluid coming from particles of solid aniline dye dropped into the channel, he was able to follow from point to point the movements of the fluid, and thus to give not only beautiful and striking ocular evidence of the truth of his early conclusions, but also to extend his theory. Papers on this subject were communicated to the Royal Society in 1876, 1877, 1878. The paper of the last-named date was entitled "On Flow of Water in Uniform Régime in Rivers and in Open Channels generally." It contains a very clear and striking account of what does occur in the motion of a river down its inclined channel; and, in particular, of the fact which seems to be ascertained, that the forward velocity of the water in rivers is, generally, not greatest at the surface with gradual abatement from surface to bottom (as would be required under the conditions supposed in the laminar theory); but that, in reality, the average velocity down stream is greatest at some depth below the surface, from which, up to the surface, there is a considerable decrease, and down to the bottom a much greater decrease. This phenomenon he showed very clearly to be due to the rising, of masses of slow-going water, from the bottom, on account of directing action of bottom obstacles. These masses of slow-going water, when they reach the top, spread themselves out, and, mingling with the quicker surface water, give to it, on the whole, a less rapid movement than it should otherwise possess. The paper, as a whole, forms a masterly exposition of this important subject.

Finally, in this brief summary must be mentioned the paper which

was made the Bakerian Lecture for the year 1892. In 1857 Professor Thomson read a paper to the British Association, on "The Grand Currents of Atmospheric Circulation." It appears that his attention was first called to this subject when, during the period of his early delicacy, his father asked him to look into the question of the Trade Winds and write a short account of this atmospheric phenomenon for a new edition of Dr. Thomson's 'Geography,' which was then in preparation. This was done; but young James Thomson found so little satisfaction in the information and theories which he then studied for the purpose that his mind was keenly directed to the question; and in 1857 he himself had formed a theory which he expounded to the British Association.

The subject was before his mind during the rest of his life; and though on account of other pressing work the complete publication of the theory was from time to time deferred, yet it was always his intention to return to the question. When in the last years of his life the affliction of partial blindness came upon him, and when he had somewhat recovered from the first depressing effects of finding himself thus sadly crippled, he set himself in his enforced leisure to complete this work, and, with the assistance of his wife and daughters, to produce the important paper which was read before the Royal Society on the 10th of March, 1892. In this paper a historical sketch is given of the progress of observation and theoretical research into the nature and causes of the trade-winds and other great and persistent currents of atmospheric circulation. Previous theories are discussed and criticised and their merits duly recognized, the theory of Hadley, in particular, being shown to be substantially true. A much more complete theory is then expounded in full detail; and charts and diagrams in illustration show the nature of the aërial motions.

Here this memoir must close. There are many papers of Thomson which have not even been alluded to in it. Nor is it possible or necessary for the present purpose to refer to all the subjects to which his ever active mind directed itself. A character so truly philosophic it is very rare to meet. His was a singularly well ordered and well governed mind. It was, if one may venture to say so, almost too philosophical and too well governed for the business of every-day life. He could scarcely realise a difference between greater and smaller error or untruth. Great or small error and untruth were to be condemned and resisted; and, perhaps, in the matter of public business and in this hurrying nineteenth century pressure, there were those who, thoroughly conscientious themselves, could not yet feel perfect sympathy with his extreme and scrupulous determination to let nothing, however small, pass without thorough examination and complete proof. To temporise was not in his nature; and this

extreme conscientiousness gave rise to a want of rapidity of action which was perhaps the cnly fault in a singularly perfect character.

Purity and honour in word and deed and thought, gentleness of disposition, readiness to spend his labour, his time, his mental energies for others, and for the good of the world in general, all were conspicuous in his life both in public and in private.

Professor Thomson was elected Fellow of the Royal Society in 1877; and he received the honorary degree of D.Sc. from the Queen's University in Ireland, and of LL.D. from his own University of Glasgow, and from the University of Dublin.

In 1853 he married Elizabeth Hancock, daughter of William John Hancock, Esq., J.P., of Lurgan, Co. Armagh, a lady who devoted herself to every minutest interest of her husband's life. They had one son and two daughters, of whom the son and elder daughter survive.

J. T. B.